CASTLEREAGH TO EDEN CASE OF NEED

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[redacted]

1 Summary

As set out in the Transmission Interface Agreement (TIA), and in particular the TIA Subsidiary document 'Development of a Need Case', as part of the pre-construction process a Need Case is prepared for a project where a requirement to modify the transmission system has been identified. A need has been identified regarding the Ballylumford to Castlereagh 110 kV double circuit.

Built in 1943, the double circuit originally terminated at Rosebank, and provided a connection between Ballylumford Power Station and the city of Belfast. Following the construction of the 275 kV network, the primary purpose of the Ballylumford to Castlereagh 110 kV double circuit is to supply Eden and Carnmoney substations; however, it also provides a limited source of resupply to Castlereagh substation. A number of issues have been identified regarding the double circuit:

- **Circuit capacity**: the relatively low rating of both conductors on the double circuit means that it is at risk of overloading- in particular following contingencies on the 275 kV network.
- **Circuit condition**: a number of condition issues have been identified on the double circuit. There is severe corrosion of the steel core of the 'B' circuit, with numerous towers along the route also subject to corrosion issues. Additionally honeycombing and spalling has been identified at many tower foundations, with numerous tower foundations also subject to mechanical loading issues.
- **Castlereagh resupply**: during maintenance season, the resupply provided by the double circuit is important in maintaining security of supply for demand connected to Castlereagh. The resupply is also important when considering High Impact Low Probability (HILP) events at Castlereagh. As demand changes over the coming years in line with decarbonisation of energy, the level of resupply provided will be insufficient during maintenance season.

[redacted]

The section between Ballylumford and Eden is already planned for refurbishment and restringing with upas conductor, and is progressing as Capital Project 1028. This report sets out the case of need for the remaining two sections between Carnmoney and Eden and Carnmoney and Castlereagh.

[1] https://tinyurl.com/yeprws4b

2 Background

2.1 Circuit history

Completed in 1943, the Ballylumford to Rosebank 110 kV double circuit tower was the first such overhead steel tower double circuit to be constructed in Northern Ireland. It consisted of Wartime Grid Reinforcement (WGR) tower design, with the two circuits being strung with different conductor types. One circuit consists of 0.15 mm^2 Cadmium Copper (CC) (rating 69/80/86 MVA) and the other consists of 0.15 mm^2 Steel Cored Copper (SCR) (rating 70/81/87 MVA). All ratings are for summer/autumn/winter respectively.

The circuit comprised four sections:

- Ballylumford to Eden, consisting of 58 towers;
- Eden to Carnmoney, consisting of 51 towers;
- Carnmoney to Finaghy, consisting of 61 towers; and
- Finaghy to Rosebank, consisting of 44 towers.

The original circuit has been subject to several modifications throughout its history, and these are detailed in the following subsections.

2.1.1 Connection into Castlereagh

In 1966, following the construction of Castlereagh substation, the section of circuit between Finaghy and Rosebank was turned into the new substation. This was achieved using L4 towers strung with ACSR Lynx conductor (rating 82/95/103 MVA). As a result, the Castlereagh to Finaghy section comprises:

- 38 WGR towers, strung with SCC/CAD conductor; and
- 4 L4 towers, strung with ACSR Lynx conductor.

2.1.2 Disconnection from Finaghy

In 1999, there was a significant reconfiguration of Finaghy substation. Following the expansion of Hannahstown 275/110 kV substation in 1998, Finaghy was reconfigured to become a transformer feeder arrangement, supplied from the newly expanded substation at Hannahstown. As part of these works, the Carnmoney to Finaghy and Castlereagh to Finaghy double circuits were disconnected from Finaghy substation. The resulting Carnmoney to Castlereagh double circuit is strung between the two terminal towers, across the Finaghy substation compound.

2.2 Present day configuration

2.2.1 Castlereagh to Finaghy section

A detailed view of the circuit route from Castlereagh to Finaghy is shown in figure 2.1. From Castlereagh substation, the circuit crosses agricultural land before traversing the residential areas of the Four Winds, Newtownbreda and Belvoir. It continues through the Lagan Valley Area of Outstanding Natural Beauty (AONB), before crossing the residential areas of Malone and Finaghy as it arrives at Finaghy substation.

Along its length, the circuit crosses some notable transport routes, including:

- The M1 motorway;
- The Belfast to Portadown to Dublin railway;
- The Upper Lisburn Road;
- The A55 outer ring Milltown Road; and
- The Saintfield Road.

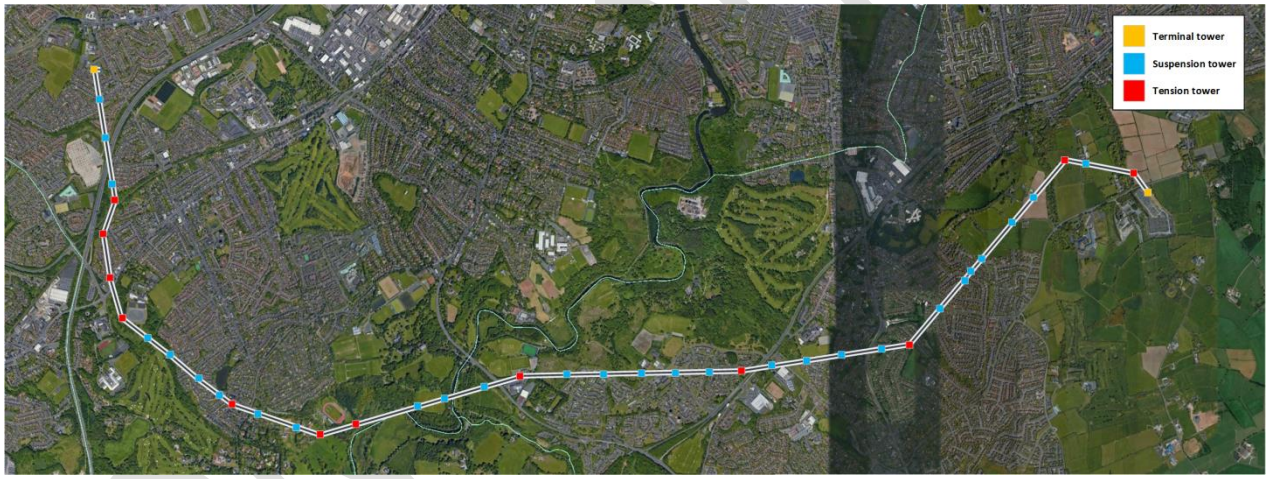

Figure 2.1: Castlereagh to Finaghy 110 kV double circuit route

2.2.2 Carnmoney to Finaghy section

A detailed view of the circuit route from Carnmoney to Finaghy is shown in Figure 2.2. From Carnmoney substation, the circuit traverses residential areas of Glengormley before crossing the M2. It continues through industrial areas of Mallusk before crossing the rural areas of the Belfast Hills. Along this rural section, the circuit passes very close to Hightown Quarry. The final 5 km of the circuit passes through numerous residential areas of West Belfast before arriving at Finaghy substation.

Along its length, the circuit crosses some notable transport routes, including:

- The M2 motorway;
- The Andersonstown Road
- The A55 outer ring Springfield Road;
- The A55 outer ring Monagh Bypass; and
- The Andersonstown Road.

Figure 2.2: Carnmoney to Finaghy 110 kV double circuit route

2.2.3 Carnmoney to Eden section

A detailed view of the circuit route from Carnmoney to Eden is shown in Figure 2.3. From Carnmoney substation, the circuit traverses residential areas of Carnmoney before following a largely rural route towards Eden. The final 3.5 km passes through residential areas of Carrickfergus. Unlike other sections of the double circuit, the Carnmoney to Eden section largely avoids major transport crossings, being situated several kilometres inland from the A2 Shore Road. The section does cross the Belfast to Antrim railway on the outskirts of Carnmoney.

Figure 2.3: Carnmoney to Eden 110 kV double circuit route

2.3 Substations along the circuit route

There are four substations along the length of the Castlereagh to Eden 110 kV double circuit, and these are discussed in the following sections.

2.3.1 Castlereagh

Castlereagh 275/110 kV Grid Supply Point (GSP) is a major substation supplying demand in south and east Belfast, and a significant part of County Down. At peak times, there is approximately 400 MVA of load supplied from Castlereagh.

The double circuit from Ballylumford to Castlereagh provides the only means of resupply to the substation at 110 kV, should a High Impact Low Probability (HILP) event occur that removes the 275 kV supply to the substation. [redacted] As the Ballylumford to Castlereagh double circuit is connected directly to the 110 kV busbar, it provides a level of resupply for this event, even if rota load shedding would be required.

Castlereagh 275/110 kV GSP is shown in Figure 2.4. [redacted] A fourth IBTx is located at the bottom of the substation, remote from the other three. As of today, it is not connected and is held as a system spare.

Figure 2.4: Castlereagh 275/110 kV GSP

2.3.2 Finaghy

As noted in section 2.1.2, the Carnmoney to Castlereagh double circuit was disconnected from Finaghy 110/33 kV substation in 1999. Presently, the circuit is strung across the substation site between the former terminal towers.

The size of the Finaghy site reflects its former function as a major switching or marshalling substation; with the development of the 110 kV double busbar at Hannahstown, this function was no longer required. Finaghy is now used as a connection point for the Bulk Supply Point for local demand and a tee of connection via a via a double circuit tower line to Donegall Main.

Finaghy 110/33 kV substation is shown in Figure 2.5.

Figure 2.5: Finaghy 110/33 kV substation

2.3.3 Carnmoney

Carnmoney 110/33 kV substation is another intermediate Bulk Supply Point along a double circuit route. It is configured as a two transformer tapping, similar to Eden, a design that was typical when the double circuit was constructed. Carnmoney also contains a pair of 33/6.6kV transformers and a 6.6 kV switchboard. Unlike Finaghy, the substation site has little scope for further development.

The substation is tightly constrained by adjacent housing and industrial premises.

Carnmoney 110/33 kV substation is shown in Figure 2.6.

Figure 2.6: Carnmoney 110/33 kV substation

2.3.4 Eden

Eden 110/33 kV substation is the last intermediate Bulk Supply Point along this double circuit route. Again, it is also configured as a tapped transformer site. Being surrounded on three sides by agricultural land, there is scope for expansion of the substation if necessary. The substation is located near both the Kilroot to Castlereagh/Tandragee 275 kV double circuit (indicated in figure 2.7) and the Kilroot to Kells 275 kV double circuit. Additionally, the substation site is located near residential developments, but is well screened with vegetation.

Eden 110/33 kV substation is shown in Figure 2.7.

Figure 2.7: Eden 110/33 kV substation

3 Issues with the circuits

3.1 Condition of circuits

An assessment of both conductors on the double circuit was carried out by a consultant, EA Technology, in 2016. Whilst their focus was on the double circuit section between Ballylumford and Eden, the findings are discussed below to indicate potential issues on the Carnmoney to Castlereagh and Carnmoney to Eden sections. It should be noted that due to the coastal location of much of its route, the conductors on the Ballylumford to Eden section are likely to be in a poorer condition than those on the other sections.

The 'A' circuit is strung with 0.15 mm^2 Cadmium Copper (CC). The consultant assessed the conductor and determined it has not been subject to corrosion; additionally, the consultant found no indication of metal fatigue from the samples taken. However, the consultant advised that metal fatigue is difficult to detect until in its final stages. It was concluded that if the circuit was to be retained the conductor would require replacement by 2026.

The conductor on the 'B' circuit is 0.15 mm^2 Steel Cored Copper. The consultant assessed a number of samples and based on its tensile strength and the requirements advised by NIE Networks the conductor was at end of life due to corrosion of the steel core and should be replaced as soon as practicable.

The refurbishment of the Ballylumford – Eden section (including its upgrade with Upas conductor as per SONI Capital Project 1028) is currently being progressed by NIE Networks through its pre-construction stage. This will see the tower line section between Ballylumford and Eden fully refurbished and restrung with upas conductor.

Whilst the conductors on the other sections are unlikely to be in as poor a condition as those on the Ballylumford to Eden section, it is assumed that they will require replacing within the next ten years.

A limited assessment comprising 8 towers on the section of the double circuit between Castlereagh and Finaghy has been performed. Both the tower foundations and the condition of the tower steelwork were assessed and it was that:

- Some degree of spalling or honeycombing was present within the foundations at the majority of the assessed towers;
- At least 13 instances where the uplift forces where expected to exceed the foundation rating[2] and

[2] A restring with Upas conductor requires the adoption of a probabilistic methodology to assess foundation strength. This leads to the assessment that many of the existing foundations would not be adequate, under the new standard.

- Varying degrees of steelwork corrosion was observed at all towers, with steelwork replacement necessary.

In terms of the foundations, based on the high proportion of defects found on the Castlereagh - Finaghy sample, it is concluded that if the tower line from Castlereagh to Carnmoney, or a section thereof, is to be retained and in order to effect a satisfactory refurbishment, the foundation of every tower would require intrusive inspection and repair. Alternatively in situations where access is restricted other methods of reinforcing the foundations could be considered.

3.2 Wayleaves

The towers were held on voluntary wayleaves with the original land owners, that were established when the tower line was constructed. [redacted]

3.3 Capacity of circuits

The Ballylumford to Castlereagh 110 kV double circuit provides a connection to Eden and Carnmoney 110/33 kV substations, a contribution to the export capacity from Ballylumford Power Station and resupply in to Castlereagh substation.

The double circuit is strung with two different conductors. One circuit consists of 0.15 mm^2 Cadmium Copper (CC) (rating 69/80/86 MVA) and the other consists of 0.15 mm^2 Steel Cored Copper (SCR) (rating 70/81/87 MVA). With the limited capacity of both conductors, there is a risk of overloading the double circuit under contingency conditions.

The most onerous contingency is the loss of the 275 kV double circuit between Hannahstown and Ballylumford/Moyle. Table 3.1 lists the percentage loading on the three sections of the Ballylumford to Castlereagh 110 kV double circuit following the contingency. The results are shown for the time of peak demand in winter, autumn and summer.

As the section from Ballylumford to Eden is planned to be refurbished with upas conductor, the results are shown for both the current network configuration (as is) and following the refurbishment (CP 1028).

Table 3.1: Percentage loading of Ballylumford to Castlereagh 110 kV circuits

Circuit	Winter		Autumn		Summer	
	As is	CP 1028	As is	CP 1028	As is	CP 1028
Ballylumford – Eden 'A'	**117**	67	**110**	63	**109**	58
Carnmoney to Eden 'A'	97	**108**	90	**100**	88	**100**
Carnmoney to Castlereagh 'A'	81	93	75	85	74	86

The results show that the Ballylumford to Eden section is most as risk of overloading for the 275 kV contingency. However, once that section is refurbished, the resulting change in circuit parameters drives larger flows on the 110 kV circuits, and so the section between Carnmoney and Eden is also at risk of overloading.

3.4 Resupply to Castlereagh

Figure 3.1 shows a high level schematic of Castlereagh 275/110 kV substation. The 275 kV busbar has two double circuit infeeds. The 110 kV busbar supplies all of the demand connected to the substation via a number of radial circuits. There is also the 110 kV connection to Ballylumford, provided by the double circuit via Carnmoney and Eden. The 275 kV and 110 kV busbars are connected through three interbus transformers (IBTx).

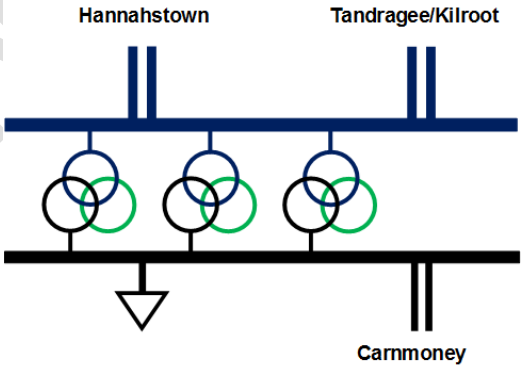

Figure 3.1: Castlereagh substation overview

3.4.1 During maintenance season

The need for resupply is important when considering maintenance season. With one IBTx at Castlereagh out for maintenance, the unplanned loss of a second IBTx leaves just one in service. With a total demand at Castlereagh greater than 300 MW, the resupply provided by

the 110 kV circuits is crucial in maintaining security of supply for this scenario. The TSSPS requires that the full maintenance period demand is supplied for such a scenario.

Table 3.2 shows the percentage loading of the remaining IBTx and the Ballylumford to Castlereagh 110 kV circuits for the maintenance trip scenario. The results are shown for both the autumn and summer peak demand periods and with and without the Ballylumford to Eden refurbishment in place.

Table 3.2: Percentage loading of Ballylumford to Castlereagh 110 kV circuits and IBTx

Circuit	Autumn		Summer	
	As is	With CP 1028	As is	With CP 1028
Ballylumford – Eden 'A'	119	65	122	64
Carnmoney to Eden 'A'	98	108	100	110
Carnmoney to Castlereagh 'A'	83	93	86	96
Remaining Castlereagh IBTX	98	93	92	85

The results show that the Ballylumford to Eden and Eden to Carnmoney sections are at risk of overloading for a maintenance trip scenario.

The results also show that the remaining IBTX would be 98% loaded under this scenario, allowing very little scope for additional demand.

3.4.2 During a HILP event

Figure 3.2 shows an image of Castlereagh 275/110 kV substation, taken from Google Earth.

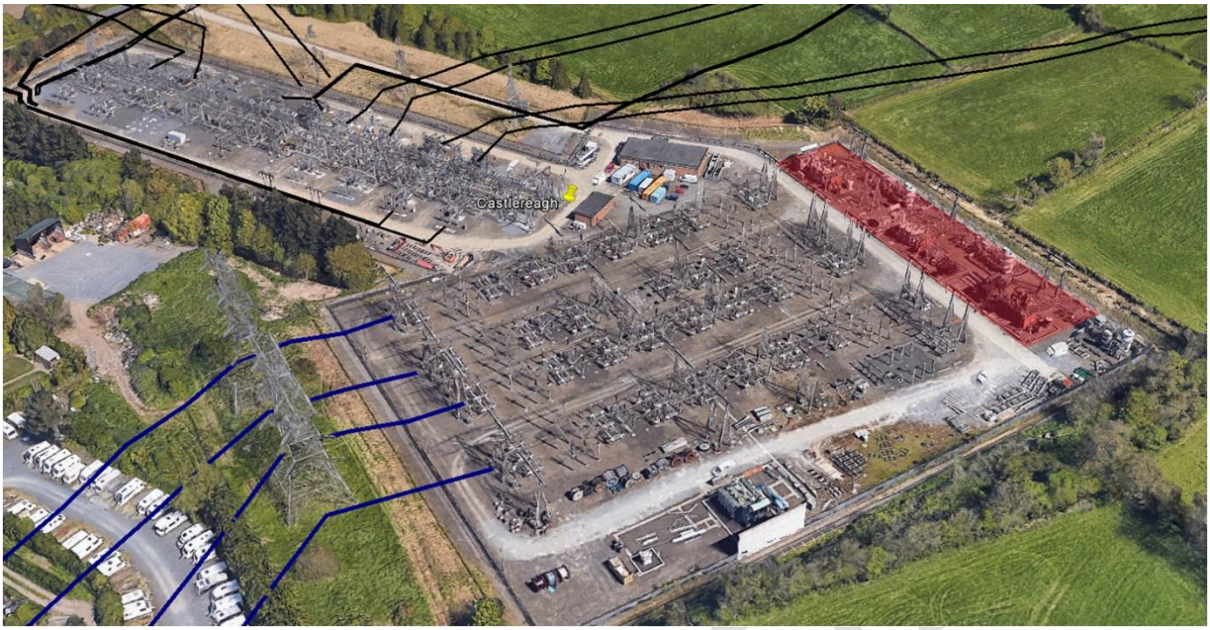

Figure 3.2: Castlereagh 275/110 kV substation

[redacted]

Table 3.3 shows the amount of demand at Castlereagh that can be supplied during the peak demand day for each season, following a HILP event. The amount of demand that cannot be supplied is also shown. As expected, there is an increase in demand that cannot be supplied

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[3] *H.P. Berg, N. Fritze, Reliability of Main Transformers, RT&A #01 (20), Vol. 2, March 2011, pg. 60*
https://pdfs.semanticscholar.org/a13e/57fda94be00bae5f25305dd5c2807c13683f.pdf?_ga=2.162659708.1595624893.1588780914-679201528.1588780914

[4] *https://www.transpower.co.nz/sites/default/files/plain-page/attachments/USI-reliability-proposal-attachment-E.pdf*

[5] *https://www.uregni.gov.uk/sites/uregni/files/media-files/2017-07-04%20RP6%20FD%20Main%20Report%20%28002%29.pdf*

Table 3.3: Resupply and unsupplied load, in MVA, for a HILP event at Castlereagh

Season	Resupply available		Unsupplied Castlereagh demand	
	As is	With CP 1028	As is	With CP 1028
Winter	108	143	312	279
Autumn	105	135	253	223
Summer	89	117	234	207

3.5 Future load growth

3.5.1 Decarbonisation of energy

Under the The Climate Change Act 2008 (2050 Target Amendment) Order 2019, the UK must reach net zero carbon emissions by 2050.

The Department for Economy NI is responsible for developing targets for Northern Ireland (NI), and is currently preparing a public engagement exercise to help shape proposals.

In advance of the setting of targets for NI it is likely that, in addition to the continued development of renewable generation, there will be requirements for electrification of transport and heating.

SONI has developed three future scenarios which provide a range of credible outcomes for the NI electricity system. The scenarios are:

- **Least Effort**, which has low uptake of electric vehicles and smart technologies and low rates of energy efficiency gains and growth of renewable generation. By 2030, overall emissions are reduced by 35% and 50% of electricity is generated from renewables.
- **Modest Progress**, where significant decarbonisation is made in electricity, heat and transport. By 2030 overall emissions are reduced by 40% and 60% of electricity is generated from renewables.
- **Addressing Climate Change**, which is a highly coordinated scenario with government policies helping the UK meet net zero emissions by 2050. By 2030 in NI, overall emissions are reduced by 45% and 70% of electricity is generated from renewables.

A public consultation into these scenarios was recently concluded with the responses presently being reviewed. As a result, the scenarios are subject to change. Figure 3.2 shows the possible impact of the Modest Progress scenario on the 2030 winter peak day demand profile for a number of Bulk Supply Points supplied from Castlereagh and Hannahstown.

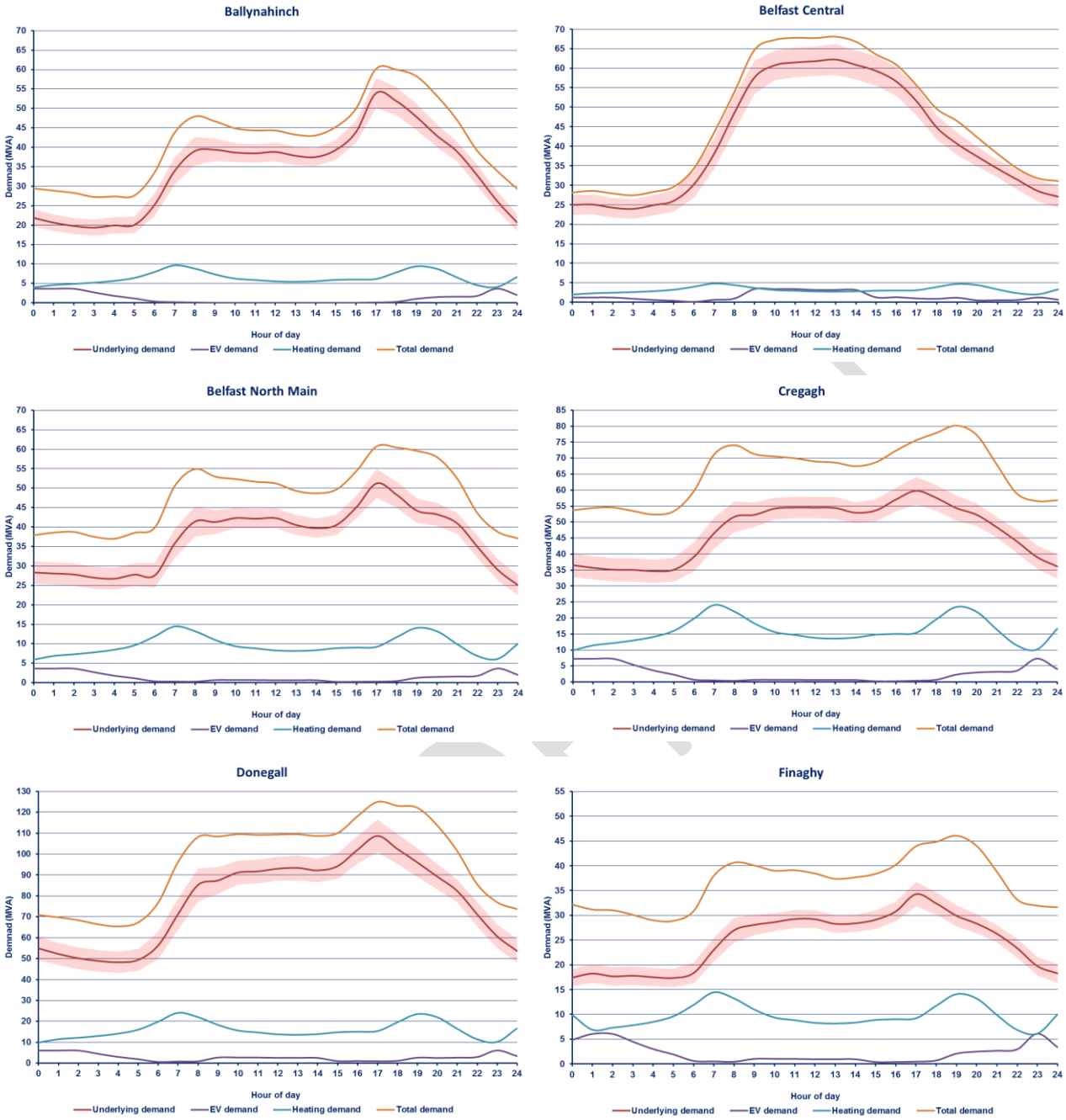

Figure 3.2: Impact of Modest Progress on 2030 winter peak demand at select BSPs

3.5.2 Implications for Castlereagh to Eden circuits

Using the potential impact on BSP demands based on the Modest Progress scenario, a similar set of analyses to those in sections 3.1 to 3.3 was performed, i.e.:

- Power flows following the Hannahstown to Ballylumford/Moyle 275 kV contingency;
- Power flows for an N-M-T event at Castlereagh; and
- Resupply for a HILP event at Castlereagh.

Table 3.4 shows the percentage loading of the three elements of the Ballylumford to Castlereagh 110 k V double circuit following the aforementioned 275 kV double circuit contingency.

As the results show, power flows have increased on all elements of the 110 kV double circuit. With CP 1028 in place, there is a risk of overloading the other two sections of the double circuit.

Table 3.4: Percentage loading of Ballylumford to Castlereagh 110 kV circuits

Circuit	Winter		Autumn		Summer	
	As is	CP 1028	As is	CP 1028	As is	CP 1028
Ballylumford – Eden 'A'	**126**	71	**121**	68	**127**	68
Carnmoney to Eden 'A'	**103**	**102**	**103**	**116**	**108**	**120**
Carnmoney to Castlereagh 'A'	87	99	88	**100**	95	**105**

Table 3.5 shows the percentage loading of the remaining IBTX and the Ballylumford to Castlereagh 110 kV circuits for the maintenance trip scenario. As shown, there is a risk of overloading both the 110 k V double circuit and the remaining IBTX at Castlereagh. With CP 1028 in place, greater supply is provided via the 110 kV circuits. This removes the risk to the remaining IBTX, but increases the overloading of the 110 k V circuits.

Table 3.5: Percentage loading of Ballylumford to Castlereagh 110 kV circuits and IBTX

Circuit	Autumn		Summer	
	As is	With CP 1028	As is	With CP 1028
Ballylumford – Eden 'A'	**134**	90	**139**	72
Carnmoney to Eden 'A'	**112**	**158**	**119**	**130**
Carnmoney to Castlereagh 'A'	95	**142**	**104**	**114**
Remaining Castlereagh IBTX	**116**	92	**105**	97

Table 3.6 shows the amount of demand at Castlereagh that can be supplied during the peak demand day for each season, following a HILP event. The amount of demand that cannot be supplied is also shown. As expected, there is an increase in demand that cannot be supplied.

Table 3.3: Resupply and unsupplied load, in MVA, for a HILP event at Castlereagh

Season	Resupply available		Unsupplied Castlereagh demand	
	As is	With CP 1028	As is	With CP 1028
Winter	108	144	361	335
Autumn	102	132	312	285
Summer	86	113	289	265

4 Conclusions

The Ballylumford to Castlereagh 110 kV double circuit is an ageing and deteriorating asset. The condition of both the towers and the conductors, as well as the capacity of the circuits, has already resulted in a planned refurbishment of the section between Ballylumford and Eden.

Analysis suggests that similar issues will be incurred by the remaining sections between Castlereagh and Eden. Refurbishment or recovery of these sections is required as soon as possible.

Normal demand growth in the Belfast area, as well as potential implications from the decarbonisation of energy, will increase the flows on the double circuit, overloading the section between Carnmoney and Eden in particular. Additionally, there will likely be a greater reliance on these circuits to provide security of supply to Castlereagh substation in the long term.

[redacted]

It is concluded that there is a need to address the condition of these assets as soon as possible, to both address the risk of a condition related failure, conductor electrical overloading and improve the level of resupply into Castlereagh. It is also necessary that any proposals take account of the long term cost of retaining towers on this double circuit in situ including potential impact on land owners in terms of natural heritage and amenity [redacted]